E7.3 10739
CR-133083

SR No. 033

(E73-10739) CARTOGRAPHIC EVALUATION OF ERTS-1 IMAGERY FOR PART OF THE UNITED KINGDOM Semiannual Report, Dec. 1972 - May 1973 (Experimental Cartography Unit) 20 p HC $3.00 CSCL 08B G3/13 N73-26345 Unclas 00739

CARTOGRAPHIC EVALUATION OF ERTS-1 IMAGERY FOR PART OF THE UNITED KINGDOM

D. P. Bickmore, M.A.,
Experimental Cartography Unit,
6A Cromwell Place, London, England.

W. P. Smith, M.A., F.R.I.C.S.,
Fairey Surveys Limited,
Reform Road, Maidenhead, England.

June, 1973.

Type II Report for Period December 1972 to May 1973.

National Sponsoring Agency:

Department of Trade & Industry,
Abell House,
John Islip Street,
London,
England.

20 pp.

CONTENTS

1. SR No.	2. Type of Report	3. Recipient's Catalog. No.
033	II	

4. Title Cartographic Evaluation of ERTS-1 Imagery for part of the United Kingdom.	**5. Report Date** June 1973. **6. Period Covered** December 1972 to May 1973.
7. Principal Investigator Mr. D. P. Bickmore	**8. No. of Pages**
9. Name and Address of Principal Investigators Organization Experimental Cartography Unit, Royal College of Art, 6A Cromwell Place, London, SW7, England.	**10. Principal Investiga. Rept. No** 2 **11. GSFC Technical Monitor** G. ENSOR
12. Sponsoring Agency Name and Address Department of Trade & Industry, Abell House, John Islip Street, London, England.	**13. Key Words (Selected by Principal Investigator)** CARTOGRAPHIC DIGITAL VISUAL

14. Supplementary Notes

15. Abstract

The study area of Central England for which data bank facilities were available, was totally obscured by cloud on the only available imagery (recorded on August 23rd, 1972), and a second study area was selected from an almost cloud free sector of the imagery. This area, centred around the City of Bristol, England, contained a variety of both natural and man-made features visible on ERTS imagery, notably the Severn Estuary; the Jurassic limestones of the Cotswold scarp and a variety of major and minor communications routes and urban developments.

Visual interpretive studies were carried out on the diapositive imagery in order to ascertain the extent to which various terrain features, broadly classified into Solid and Drift Geology, Topography and Land Use; were depicted on the four independent imagery bands.

Quantitative assessment of the accuracy of map content suggests that the imagery is inadequate for most mapping purposes within the area of study, at least, using traditional interpretation methods. Further work is to be undertaken using a new multi-spectral viewer produced by Faireys.

Analysis of the first digital tapes has so far been limited to replotting and boundary derivation, together with production of a ground registration program and digitisation of ground truth.

INTRODUCTION

This document comprises the first six monthly report to NASA on progress with the cartographic analysis of imagery derived from the ERTS-1 multi-spectral scanner. Unfortunately, the only available imagery was one scene, in which the bulk of the main test area (Upper Thames Valley) was covered by cloud. By way of expediency, an adjacent area was chosen for analysis. For convenience, this was delimited by the area covered by the British Ordnance Survey 1:63,360 map sheet 156, centred on the City of Bristol (Figure 1).

The report falls into three sections. Section 1 describes the methods used in the visual analysis and includes the photo-interpreter's evaluation. Section 2 comprises an assessment of the accuracy of the map content. Because of the manual methods used for mapping, this analysis is more or less confined to map content and does not include an analysis of positional accuracy. Section 3 describes work connected with the digital tapes.

Summary notes on cartographic interpretation from the ERTS imagery.

J. Wooldridge, B.Sc.,
Fairey Surveys.

Earth Resources Technology Satellite 1 was launched on July 23rd 1972, and two days later entered a circular sun synchronous polar orbit at an altitude of approximately 900 kms.

ERTS-1 carried a sensor payload consisting of a Return Beam Vidicon camera sybsystem (RBV), and a Multispectral Scanner (MSS) filtered to record imagery in four distinct bands within the 0.5-1.1 micrometer wavelength region. Despite systems failures in recording and switching gear which necessitated that the RBV be switched off early in the programme, the MSS and back-up recording and telemetry systems continued to function for some time; relaying back to ground receiving stations scanned imagery data covering extensive areas of the earth's surface. (1).

During mid morning of August 23rd 1972, MSS imagery was obtained of the Central England area and was later sent to the U.K. for further study. As part of a programme designed to ascertain the value of Satellite imagery as a means of loading and up-dating a Land Resource Data Bank facility, the multispectral imagery was subjected to a lengthy examination in order to determine which terrain features were best depicted by each spectral band.

The material upon which the study programme was based consisted of diapositive imagery in bandwidths:

0.5 - 0.6 micrometers	Blue-Green
0.6 - 0.7 "	Orange-Red
0.7 - 0.8 "	Red-"Photographic" I.R.
0.8 - 1.1 "	Near Infra-Red

All four images showed the same 185 x 185 km. square area of Central England at a contact scale of approximately 1/1,000,000. (2). Since all four bands were recorded simultaneously by the MSS Sensor array from the same flight path it was possible to directly assess the relative value of each band as a means of locating the various terrain features.

Though partially obscured by cloud the imagery was nevertheless of good quality with a ground resolution estimated to be in the region of 160 metres for high contrast targets. (3). Many Linear features having a width of less than this figure were clearly visible on the imagery however, particularly when orientated perpendicularly or at an acute angle to the Scan Lines. On Infra-Red imagery, rivers and water bodies having widths down to about 40 metres could be resolved.

Of the cloud free areas a special study was made of the Bristol, Severn Estuary and Cotswold region which was closely examined on all four bands, against a ground truth background of geological and topographic maps.

The content and appearance of the four bands varies considerably. Shorter wave imagery appearing flat and relatively featureless, by comparison with the higher contrast and larger number of immediately recognisable features visible in the longer wave Red, and near Infra-Red imagery.

Few terrain features appeared to have been recorded exclusively by any one imagery band, and most were represented on all four bands, often varying considerably in appearance and reflective properties. Most features which image palely on dispositive imagery in the 0.5-0.7 micrometer region, appear very dark on 0.7-1.1 micrometer imagery indicating an abrupt shift from reflection towards almost total absorption by the surface material at a point near the limit of the visible spectrum. The converse also appears to be true, for whilst most Motorways, large roads and Airport runways image palely on Orange-Red imagery but in dark tones on Infra-Red, many areas of vegetation are highly reflective to Infra-Red but record only poorly and in dark tones within the visible spectrum.

Man-made features such as roads and built-up areas become more obviously discernible at increasingly long wavelengths and Urban spread can be readily established by direct comparison of the I.R. Satellite imagery with existing map coverage.

Water bodies such as reservoirs, lakes, canals and rivers record characteristically on Infra-Red imagery as sharply defined black areas due to the almost total absorption of incident I.R. radiation at the water surface. By contrast, shorter wave Orange-Red imagery exhibits a reasonable degree of water penetration, the Severn Estuary being adequately sharply and clearly depicted in terms of tonal gradations to allow the positions of the main channels to be plotted, and the locations of the major sand bars to be determined.

The Blue-Green waveband was perhaps the best source of meteorological data, permitting cloud types and their inter-relations to be rapidly established. Terrain features appeared poorly contrasted and it was difficult to delineate between land and estuarine features. Woodlands were readily identifiable, with dense coniferous forests appearing somewhat darker than deciduous, at the season during which imagery was acquired. Forestation was also visible on Orange-Red imagery but boundaries were difficult to locate and confusion could arise in attempting to segregate adjacent Urban and Woodland features.

Woodlands were also of value in helping to locate the positions of wooded river and stream valleys and certain other areas having a steep slope. The Cotswold Scarp Line could be traced for much of its length on Blue-Green imagery by the occurence along the slope of narrow bands of woodland. However, since no true stereo "lift" can be obtained from ERTS imagery, the precise level at which these woods grow on the scarp face, and on which geological horizon, cannot be decided without recourse to suitable maps or field examination.

Regional geological patterns were surprisingly well presented, being emphasised by changes in the pattern of agriculture and vegetation with lithology. This was particularly well shown on Orange-Red imagery. Clay areas such as the Lower Lias of the sub-scarp vale around Chipping Sodbury appear homogenous and dark in tone with little trace of field pattern. Away from the fringing woods of the scarp line however, the Oolite limestone is evidenced by an area of high Orange reflectance and large field patterns. The oolite "feather edges" south eastwards under a sequence of Upper Jurassic sands and clays, again typified by homogenous dark tones and little discernible field detail. The junction of Greensand and Gault with the Chalk is clearly marked by a return to conditions of large patchwork and high Orange-Red reflectivity. North of Salisbury Plain the outline of a major tongue of Greensand and Gault into the chalk can be readily distinguished.

Non-geological forms of terrain classification, such as large scale crop distribution analysis, can be carried out from satellite imagery on a basis of such factors as relative reflectance in the opposed spectral bands particularly 0.6-0.7 and 0.7-0.8 micrometers. Linearity, continuity and granularity of features and their relative scale and tonal contrasts also have significance. These factors can be combined to form a series of signatures which may be recognised as distinct and can be mapped from the imagery. As with geological interpretation however, accurate ground truth is essential to relate the satellite mapped units to actual ground features.

In all cases the imagery contained more usable data than was at first apparent, and the four wavebands together contributed to present a useful record of the major Topographic, Land Use and Geological features of the area.

The imagery was supplied by NASA and this study was carried out as part of a project in which the Experimental Cartography Unit (Mr. D. P. Bickmore) and Fairey Surveys (Mr. W. P. Smith) were co-investigators, to both of whom my thanks are due.

References and Data Sources

(1) Department of Trade and Industry, Space Division Personal Communication.

(2) NASA. Earth Resources Technology Satellite - Data Users Handbook. Document 71SD 4249

(3) Finch W. A. Proceedings of the ERTS-1 Participants Symposium September, 1972.

SECTION 2: ASSESSMENT OF THE PHOTO-INTERPRETATION MAPS

J. A. A. Jones, M.Sc.
Experimental Cartography Unit

The following comments and tables are based on the 1:63,360 photo-interpretation overlays produced by John Wooldridge of Fairey Surveys from the initial ERTS-1 MSS imagery of the Bristol area taken on August 23rd, 1972. The techniques he used are described in Section 1 of this report. "Notes on cartographic Interpretation". Broadly, he carried out conventional photo-interpretation based on each of the four wavebands individually and used the O.S. topographic sheet (156) as a geodetic base, and produced separate overlays for topography, land-use and solid and drift geology for each band, i.e. 16 overlays in all. In general, because of the nature of the mapping techniques used, evaluation has been confined to content rather than locational accuracy.

2.1 Linear topographic features

Although most such features are narrower than the nominal ground resolution of the imagery of c. 100 m, it is a well-known fact that such linear features can often be picked out by the human eye. Two major linear features were selected for testing, namely roads and rivers.

Table 1 compares the total length of mapped roads in four different MOT categories with the total length of mappable road on the Ordnance Survey reference sheet. It indicates reasonably satisfactory mapping of motorways from the infrared and red bands, but quite unsatisfactory mapping for the lower categories of road and in the other two wavebands.

Table 2 is a break-down of the length of roads mapped in the various bands into the photo-interpreter's chosen classes of ease of interpretation or "degree of clarity". In this he took a five point scale varying from "definite" (grade 1 in Table 2) through "obscure" (grade 4) to "inferred but with no definite map location". The table shows that the only band in which even the motorways are definite is the near infrared.

Table 3 compares the total length of mapped rivers as divided into three categories: finger-tip tributaries (order 1 in the table), streams formed by the direct combination of two or more finger-tip tributaries (order 2) and the larger rivers (order 3). Order 3 and above includes the major rivers of the area, the Wye, Avon, Frome and Little Avon. Measurements were extended downstream as far as the O.S. tidal water boundary. No individual category of river is adequately mapped, although the broader downstream reaches of all the major rivers appear on the red and infrared maps.

The breakdown of ease of interpretation in Table 4 shows that no rivers were very clear. Often they have been inferred from the presence of lusher vegetation and wetter soils in the adjacent valleys and flood plains.

2.2 Areal topographic and landuse features

Two areal features were chosen from the topographic and landuse overlays for analysis for which "ground truth" is available, that is, urban and rural settlement and woodland.

Table 5 lists the results of evaluation of the numbers of settlements visible on the different images. This shows that the infrared band is best for settlement recognition, but even here only a quarter of the settlement areas are visible. Map content is inadequate in all other bands.

Table 6 is an attempt to measure the accuracy of delimiting the built-up area and was confined to Greater Bristol mainly in order to reduce inaccuracies caused by the area measurement technique (grid cell count) in small areas. This shows reasonably good delimitation in all bands except the green, but with a slight tendency to over-estimate area in the red and infrared. This tendency was observed to be more marked in small settlements presumably because of blurred edges on the imagery and the relatively greater proportion of the total area occurring in these marginal zones.

Analysis of woodland representation was made in terms of the recognition or non-recognition of woodland at points of discrete units of woodland on the O.S. sheet, whether or not the woodland on the photo-interpreted overlay was merged with adjacent woods. Infact, merging of woodland and over-estimation of woodland area was common for the woodland units that were recognised by the photo-interpreter.

Table 7 shows the recognition of woodland panels in the various bands, broken down into woodland units of one square kilometre or more in area or of between a quarter and one square kilometre. Smaller woodlands were not generally recognised as individual units from the imagery, except in a few cases where they were associated with parkland. The table shows a reverse trend in the interpretive value of the various wavebands compared with all of the previously analysed features.

The highest degrees of recognition are in the shorter wavebands, that is, throughout the visible range generally. There is no clear difference within these bands. The green or chlorophyll reflectance band is good, but does not appear to be significantly better than the orange or red for purposes of discrimination in this area. The proviso "in this area" is important and it applies to all the features described, since clarity of a feature depends as much on the reflectance or radiance of its surroundings (both colour and contrast) as it does on the features own inherent reflectance and radiance. Differences must therefore, be expected from one area to another and, indeed, from one time to the next. This militates against the value of a "data bank" of reflectance and radiance "signatures".

2.3 Geology

John Wooldridge admits in his notes on the overlays that "over the area under study little geological data can be truthfully derived".

In fact, the overlays of drift geology appear to be reasonably accurate interpretations, although there is very little in the way of drift deposits in the area. Alluvium is the main one. This seems to be best mapped in the red and infrared bands. The green band overlay shows very little except for a rather expanded area along the River Frome in the north and some along the River Avon upstream from Chippenham. It omits the estuary deposits of alluvium. The orange band is a little better, but not as complete for the main estuary areas as the red and infrared. Curiously, the shrips of river alluvium do not figure on these. This may be due to different drainage conditions and vegetation, and possibly different grades of parent alluvium in the two depositional environments.

In the solid geology overlays the Jurassic scarp and scarp-slope combes, defining the edge of the Great Oolite, are generally well mapped. There seems to be a slight tendency for better mapping in the shorter wavelengths, probably because of differences in vegetation reflectances.

In general, little detail could be interpreted on the solid geology. Only a hint of the coal basin north-east of Bristol was apparent in the two shorter wave-bands, but oddly displaced about 3 kilometres to the north of its true position. This may be because the interpreter has picked up evidence from some stratigraphic banding north of the Coal Measures not mapped on the Geological Survey 1:63,360 sheet, although he actually interpreted it as the boundary of the Upper Coal Measures. Alternatively, it maysimply be misplaced because of inadequate locational reference. The boundary between limestone and sandstone in the Forest of Dean was also rather inaccurate on all bands. This may be at least partially due to slight obscuration by cloud according to the photo-interpreter's notes, despite the fact that the area was chosen as cloud-free.

SECTION 3: DIGITAL ANALYSIS

ECU received the first set of digital tapes in February, 1973. Although precision products were originally ordered, there now seems to be some doubt that the 4 MSS tapes despatched were, in fact, precision processed, especially since NASA appears to have mislaid the ground control data for the target area.

These tapes have been read on the IBM 360/65 at University College, London, and have so far been used in testing three programs. These are: (1) a program to re-organise the data values on the tapes into a logical west-to-east scan sequentially and subsequently to create one tape file for one spectral slice, in order to facilitate comparison with ground truth data; (2) a program to identify boundaries in the four cardinal directions; and, (3) a program to plot out digital grey scale and/or derived boundary data on a Calcomp 1670 microfilm plotter. All of these programs have been successfully tested. The tape re-organisation program has not been run in a complete "production" capacity, since the cloud-free area is not the original "data bank" area for which most of our ground truth has been digitised (see below) and since it makes a relatively large demand on computer facilities (2 tape drives and 60 cylinders of disk space). It would be preferable to reserve "production" runs for the latest imagery (November, 1972), for which digital tapes were ordered on March 28th, 1973.

The boundary derivation program (see section of first Type 1 Report to NASA, November, 1972) at present outputs to lineprinter, but the facility has been included in the microfilm plotting program for future output onto microfilm. Currently, however, microfilm plotting has been held up by the lack of suitable data packing in the University College Computer Centre software for creating Calcomp tapes on the 360. It is only capable of plotting about five ERTS scan-lines per mag tape. The derived boundary map has been held as a binary field, equivalent to the ERTS scene. However, it is possible to convert this into a series of X, Y co-ordinates for each point on the boundary and as a first step this is being done to reduce the problem of inefficient blocking on the microfilm tapes. This should be sufficient at least to plot a complete ERTS "strip" on microfilm without further packing. Nevertheless, University College have been asked to give priority to the blocking problem.

In addition to work with ERTS tapes, the ECU has been engaged to two other activities, viz., transformation programs for registration with ground truth and ground truth digitising. In February, 1973, the ECU completed outline digitisation of the major topographic features on O.S. sheet 156 and produced an IBM compatible tape. This has since been successfully put through a program written to convert the line digitised data into raster format (see first Report). However, test plots have so far only been made using the line digitised data, since successful replotting in raster format must await modification of the micro-film software. Meanwhile, the ECU has also nearly completed full digitisation of roads, rivers and woods in the western half of the main test site (Upper Thames Valley) and is progressing with the eastern half. Together with the geological and soil survey maps already digitised for this area, this forms the basis of the ground truth data bank against which the latest cloud-free imagery of November 11th, 1972, will be tested when the digital and photographic products become available.

Work on geometric correction and fitting to ground truth is being undertaken as part of the ERTS project and as part of a project to rectify oblique imagery from the British Aircraft Corporation's Skylark rocket. Geometric correction may logically be undertaken at one of two critical stages in the process of map production. It may be performed on the original imagery or on some derivative map produced by interpretation of the imagery. To a large extent, this choice may be governed by the format of the original imagery. If that imagery is not already in digital format or readily convertible to a digital format, for example, by scanning spot microdensitometer, then operations on the original imagery could be achieved by using sophisticated, purpose-built optical equipment. In such cases prior photo-interpretation and subsequent line co-ordinate digitisation of the photo-interpretation map, using equipment such as the Bendix (Ferranti) or d-mac digitising tables, could produce a digital map containing ground control points and line detail and suitable for processing through a digital computer.

Similar extraction and digitisation of selected ground control points may also prove valuable for registration purposes even when the original imagery is available in digital format. This is because of the difficulties inherent in automatic recognition of the selected ground control points in the digital tape record. Once calculated, the corrections may be applied to each resolution element of the digital image record or to each digitised X, Y co-ordinate pair within the area of the transformation.

Two basic methods are available for this rectification and registration: a best fit by least squared difference criteria based on selected corner points or a direct mathematical mapping of the set of corner points from the imagery or its derivative map into the set of the corner points as they appear on a geodetic map. Both of these methods may be applied either to the whole of an image (scene) or to parts of the image by piece-wise fitting, depending on the degree and nature of the distortion in the original imagery, the desired level of geometric accuracy and the amount of effort considered reasonable to approximate this.

The direct conversion of data from one system to another can be accomplished by a generalised matrix, known as the affine transform, which will effect the desired transformation between the selected control points in the two systems. This matrix is then applied to all the points contained within the boundary formed by joining the control points. Under certain circumstances, i.e. when the transforms between adjacent boundaries are very different, discontinuities are introduced across the boundary. This condition dictates that certain constraints must be applied in the regions of the boundaries, where the discontinuities are large, in order to minimise this effect. It is this direct mapping method and the associated problems of boundary constraints with which the current work at the ECU is concerned.

At this stage two programs have been written and tested, respectively, for three and four point affine transforms and some initial test data have been derived from Skylark imagery of the Argentinian pampas. It is expected that a single four point transform will be sufficient for ERTS data, but more sophisticated patching routines will be needed for the rocket imagery.

TABLE 1

Percentage length of roads visible on ERTS-1 imagery of the Bristol area, outside urban areas.

class of road / waveband	% of length of road in each class				
	M	A	B	Minor	% of total length of road
0.8 - 1.1 µm	98%	34%	12%	0	10.2%
0.7 - 0.8 µm	86%	38%	11%	~0	10.1%
0.6 - 0.7 µm	19%	9%	0	0	2.1%
0.5 - 0.6 µm	18%	5%	0	0	1.4%

TABLE 2

Ease of interpretation of road networks. Percentages of total length of each category of road.

	waveband and degree of clarity \ class of road		M	A	B	Minor
1.	0.8 - 1.1 µm	1 *	98%			
		2		20%	7%	
		3		9%	5%	
		4		5%	<1%	
		5				
2.	0.7 - 0.8 µm	1				
		2	61%	3%		
		3	20%	15%		
		4		14%	7%	
		5	4%	6%	4%	~ 0
3.	0.6 - 0.7 µm	1				
		2				
		3		4%		
		4	16%	5%		
		5	2%	< 1%		
4.	0.5 - 0.6 µm	1				
		2		2%		
		3	6%	< 1%		
		4		3%		
		5	10%			

* Clarity scale 1= definite, grading to 4 = obscure and 5 = inferred but with no definite map location.

TABLE 3

Percentage length of rivers visible on ERTS-1 imagery of the Bristol area.

Strahler order of stream / waveband	1	2	> 3	% of total
0.8 - 1.1 µm	1%	21%	35%	10.9%
0.7 - 0.8 µm	< 1%	13%	28%	7.9%
0.6 - 0.7 µm	~ 0	4%	13%	3.4%
0.5 - 0.6 µm	0	0	10%	2.0%

TABLE 4

Ease of interpretation of river networks. Percentages of total length of each order of stream.

	waveband and degree of clarity \ Strahler order of stream		1	2	> 3
1.	0.8 - 1.1 μm band	1			
		2			
		3			26%
		4	1%	21%	9%
		5			
2.	0.7 - 0.8 μm band	1			
		2			1%
		3			23%
		4	< 1%	10%	4%
		5		3%	
3.	0.6 - 0.7 μm band	1			
		2			
		3			9%
		4	~0	4%	4%
		5			
4.	0.5 - 0.6 μm band	1			
		2			
		3			3%
		4			7%
		5			

TABLE 5

Recognition of settlements and urban areas: numbers recognised in whole or part.

band \ feature	towns (>10,000 pop)*	other settlements (excluding "hamlets")	% of total settlements
0.8 - 1.1 µm	100.0%	17.5 %	23.3%
0.7 - 0.8 µm	66.7%	11.7%	15.5%
0.6 - 0.7 µm	55.6%	1.7%	5.4%
0.5 - 0.6 µm	0	0	0

TABLE 6

Built-up areas of Bristol.

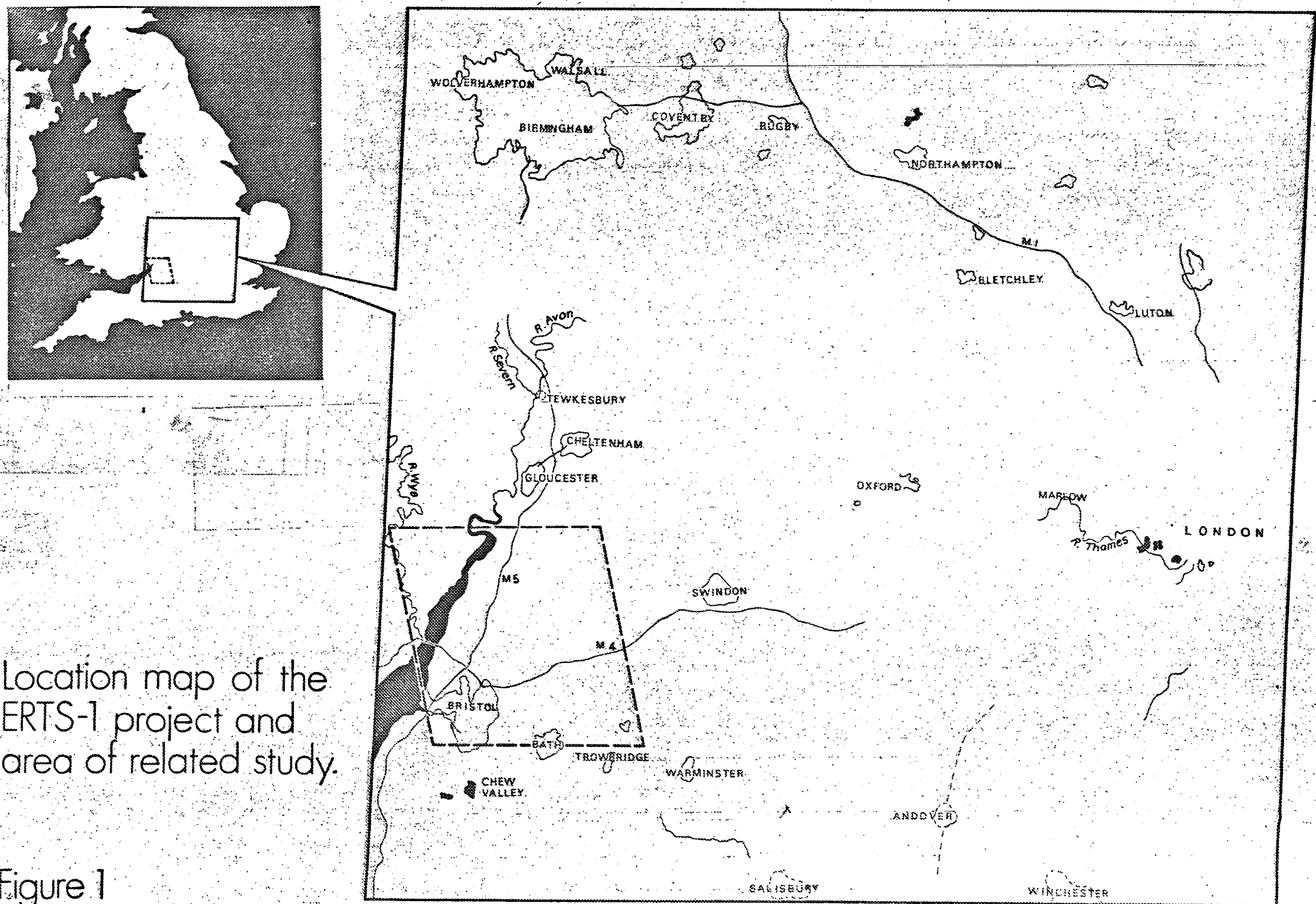
Band	PI built-up area as % true built-up area
0.8 - 1.1 µm	104.3%
0.7 - 0.8 µm	104.8%
0.6 - 0.7 µm	96.2%
0.5 - 0.6 µm	0

* 1961 census data. O.S. classification. Only 9 such towns fall in the area.

TABLE 7

Recognition of woodland. (Percentage of contiguous woodland areas in each category).

band	areas > 1 km^2 boundary identification			Sub-total	area between 0.25 and 1 km^2 boundary identification			Sub-total	Overall total
	definite	doubtful	none		definite	doubtful	none		
0.8 - 1.1 μm	4.0	36.0	20.0	60.0%	0	0	0	0	17.4%
0.7 - 0.8 μm	9.5	66.7	4.8	81.0%	1.5	9.2	10.8	21.5%	36.0%
0.6 - 0.7 μm	33.3	33.3	4.8	71.4%	4.6	13.8	15.4	33.8%	43.0%
0.5 - 0.6 μm	19.0	57.1	4.8	81.0%	0	20.0	1.5	21.5%	36.0%



Location map of the ERTS-1 project and area of related study.

Figure 1

19